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Potential human health risks from toxic metals via mangrove snail consumption and their ecological risk assessments in the habitat sediment from Peninsular Malaysia

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HIGHLIGHTS

- We examined the distributions of heavy metals in *Nerita* snails and surface sediments.
- We determined the potential human health risks from metals via mangrove snails consumption.
- We estimated their ecological risk assessments in the mangrove snail habitat surface sediments.

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ABSTRACT

Samples of mangrove snails *Nerita lineata* and surface sediments were collected from nine geographical sampling sites in Peninsular Malaysia to determine the concentrations of eight metals. For the soft tissues, the ranges of metal concentrations (μg g^{-1} dry weight (dw)) were 3.49–9.02 for As, 0.69–6.25 for Cd, 6.33–25.82 for Cu, 0.71–6.53 for Cr, 221–1285 for Fe, 1.03–50.47 for Pb, and 102.7–130.7 for Zn while Hg as 4.00–64.0 μg kg^{-1} dw^{-1}. For sediments, the ranges were 21.81–59.49 for As, 1.11–2.00 for Cd, 5.59–28.71 for Cu, 18.93–62.91 for Cr, 12 973–48 916 for Fe, 25.36–172.57 for Pb, and 29.35–130.34 for Zn while for Hg as 2.66–312 μg kg^{-1} dw^{-1}. To determine the ecological risks on the surface habitat sediments, sediment quality guidelines (SQGs), the geochemical indices, and potential ecological risk index (PERI) were used. Based on the SQGs, all the metals investigated were most unlikely to cause any adverse effects. Based on geoaccumulation index and enrichment factor, the sediments were also not polluted by the studied metals. The PERI values based on As, Cd, Cu, Cr, Hg, Pb and Zn in this study were found as 'low ecological risk'. In order to assess the potential health risks, the estimated daily intakes (EDI) of snails were found to be all lower than the RfD guidelines for all metals, except for Pb in some sites investigated. Furthermore, the calculated target hazard quotients (THQ) were found to be less than 1. However, the calculated total target hazard quotients (TTHQ) from all sites were found to be more than 1 for high level consumers except KPPuteh. Therefore, moderate amount of intake is advisable to avoid human health risks to the consumers.

1. Introduction

Seafood consumption has been identified as the major pathway of human exposure to heavy metals, and consuming the mangrove molluscs could potentially threaten the health of the consumers (Bodin et al., 2013; Liu et al., 2014). Metals As, Cr and Hg, potential human health risks from toxic metals via mangrove *Nerita* snail consumption and their ecological risk assessments in the habitat sediment were not included in the previously reported studies (Amin et al., 2006, 2008, 2009; Yap et al., 2009, 2010; Yap and Cheng, 2009, 2013; Palpandi and Kesavan, 2012; Cheng et al., 2012, 2013a,b). A lot of anthropogenic discharges and natural releases have caused enrichment of toxic heavy metals in the mangrove ecosystem, where they can be readily assimilated and accumulated by various intertidal molluscs and may result in potential risk for human health through food chain. Hence, it is of paramount importance to determine the concentrations of heavy metals in shellfish and to reasonably evaluate their potential risk on human health.

To assess the potential health risks associated with trace metal contamination due to consumption of molluscs, a screening-level risk assessment are usually conducted through consideration of internationally accepted dietary guidelines and the calculation of estimated daily intakes (EDI) and target hazard quotients (THQ).

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The EDI and THQ values were calculated to evaluate the non-carcinogenic health risk from individual heavy metal and combined heavy metals due to dietary intake (Zheng et al., 2007). THQ value proposed by USEPA (2000) is an integrated risk index by comparing the ingestion amount of a pollutant with a standard reference dose and has been widely used in the risk assessment of heavy metals in contaminated foods (Storelli, 2008). The THQ value has been recognized as one of the reasonable parameters for the risk assessment of heavy metals associated with the consumption of contaminated shellfish (Zheng et al., 2007; Storelli, 2008). The value of THQ above 1 (i.e., THQ > 1) means that the exposed population via the consumption of contaminated foods is likely to experience obvious deleterious effects. The higher the THQ value is, the higher probability of the hazard risk on human body will be. Based on the THQ values, several studies on the potential risk assessment of dietary intake of heavy metals via the consumption of seafood have been reported (Zheng et al., 2007; Storelli, 2008). THQ has been widely used in the literature for crops, shellfish and vegetables for the estimation of health risk assessment of heavy metals. For example, Zhao et al. (2013) reported that, based on EDI and THQ, there were no potential human health risks to Dalian City consumers of marine bivalves. Li et al. (2013) reported that, based on EDI, the intakes of heavy metals by consuming shellfish collected from Xiamen of China did not present an appreciable hazard risk on human health.

In order to assess ecological risks for As and metals in sediments, three approaches were employed. The first was to apply three sets of sediment quality guideline (SQG)s developed for marine and estuarine ecosystems (Long et al., 1995; Long and MacDonald, 1998; Chapman et al., 1999) via (a) the effect range low (ERL)/effect range median (ERM)/interim sediment quality value-low (ISQV-low) and (b) the threshold effect level (TEL)/probable effect level (PEL)/interim sediment quality value-high (ISQV-high) values. The second approach, developed by Hakanson (1980) who first introduced the contamination factor (*Cf*), potential risk of individual metal (*Er*) and the sum of potential risk of individual metal (*RI*), and degree of contamination concepts as diagnostic tools for pollution control purposes. The third approach was to apply two geochemical pollution indexes including index of geoaccumulation (Igeo) by Muller (1969) and enrichment factor (EF) defined by Buat-Menerd and Chesselt (1979). All the three approaches of ecological risk assessments have been widely used in the literature such as from Khuzestan coastal waters, Iran (Madiseh et al., 2009), Northern Bohai and Yellow Seas, China (Luo et al., 2010), Dongjiang Harbor, China (Guo et al., 2010), Yangtze Estuary, China (Zhao et al., 2012), Lake Çıldır, Turkey (Kukrer et al., 2014) and Ulsan Bay, Korea (Ra et al., 2014).

The objectives of this study were to (1) to examine the distributions of heavy metal concentrations in *Nerita lineata* snails and surface sediments collected from the west southern coast of Peninsular Malaysia, (2) to determine the potential human health risks from heavy metals via mangrove snails consumption, and (3) to estimate their ecological risk assessments in the mangrove snail habitat surface sediments from Peninsular Malaysia.

2. Materials and methods

2.1. Sampling and sample preparation

The snails *N. lineata*, and surface sediments (0–10 cm) were randomly collected from nine sampling sites in the mangrove area of Peninsular Malaysia in April 2011 (Fig. 1). About 20 individuals of the snails of similar size were selected from each sampling site, the total soft tissues were dissected from the shells. The size range measurements for the nine populations were 19.56–33.82 mm, 14.56–22.80 mm and 7.45–18.19 mm, for shell lengths, shell widths and shell heights, respectively.

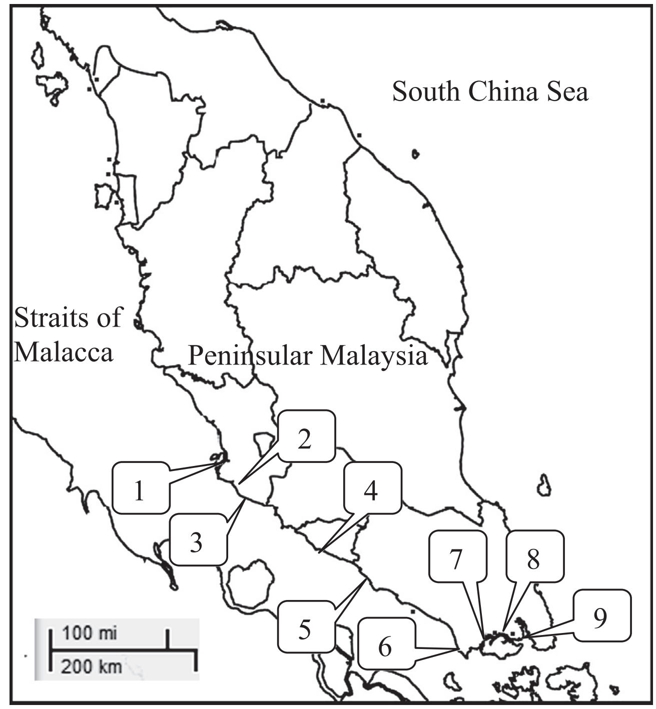

Fig. 1. Sampling map for mangrove snails and surface sediments in Peninsular Malaysia. Number of sampling sites follow those in Table 1.

2.2. Metal analysis

Before acid digestion, the snail soft tissues were dried at 60 °C until constant dry weights. Triplicates of 20 dried grinded individual soft tissues, with an approximate amount of 0.5 g each, were placed in the tetrafluormetoxil (TFM) vessels. A mixture of acids (7 ml of HNO_3 65% + 1 ml H_2O_2 30%) were added to the dried samples before inserting them into the microwave cavity. The microwave digester used was the Milestone ETHOS labstation with easyWAVE or easyCONTROL software HPR1000/10S high pressure segmented rotor. The microwave digester were set to increase the temperature to 200 °C for the first 10 min and maintained at 200 °C for the following 20 min, with the application of 1000 W of microwave power. The samples were left in the microwave digester to cool down to room temperature for 10 min after the digestion is completed. Digested samples were then diluted to 100 ml with double distilled water (DDW) and filtered with Whatman No. 1 filter paper before they were stored for metal analysis.

For surface sediments, the sample were dried at 60 °C until constant dry weights (dw) and sifted with a stainless steel sift of 63 μm in mesh. Triplicates of 0.5 g each were obtained from the sampling sites and placed in TFM vessels. A mixture of acids (9 ml of HCl + 3 ml of HNO_3 65%) were added to the dried sediment samples. Similar digestion procedures from the snail preparation were applied to the sediments but with a temperature raised to 200 °C for the first 10 min and maintained at 200 °C for the following 15 min.

After filtration, the prepared samples of snails and sediments were analyzed for As, Cr and Hg by using an Inductively Coupled Plasma-mass Spectrometer with Dynamic Reaction Cell™ (ICP-MS DRC^{plus}) (Perkin Elmer ELAN DRC^{plus}). For the determination of Cd, Cu, Fe, Pb and Zn, flame technique Atomic Absorption